

## RIVERS AND FLOODS.

The flood of January, 1907, in the Ohio Valley was, below the mouth of the Great Kanawha River, one of the greatest of authentic history, the records in some cases extending back between seventy-five and ninety years.

In point of importance it ranks perhaps third, yielding only to the floods of 1883 and 1884, that of the latter year easily standing alone, when both extent of overflow and heights of flood planes are considered.

The precipitation conditions preceding and attending the three floods were very similar, except that in 1907 there was marked deficiency over the Tennessee watershed, while in 1884 there was a decided excess there, and a more moderate one in 1883. Chart X therefore gives a very good general idea of the precipitation that caused the three floods.

The floods of 1883 and 1907 were not at all unusual above the mouth of the Great Kanawha River, but that of 1884 easily exceeded all previous records, except at Pittsburg, where the crest stage of 33.3 feet was 1.7 feet below the great high-water stage of February 10, 1832. The excess in 1884 of 10 feet or more above the mouth of the Great Kanawha was doubtless responsible for that below; otherwise the stages at all three floods would have been practically alike. The cause of the upper river excess in 1884 is not entirely apparent. No detailed statement as to antecedent conditions was available, and a careful investigation of weather and temperature conditions failed to disclose any reason for the abnormally high stages of water. It is probable that unreported accumulated snows were largely responsible.

During the month of December, 1906, the precipitation was in excess from one to more than two inches over the entire watershed of the Ohio River with the exception of the Allegheny and Tennessee. The temperatures also were high for the season. The new year therefore found the soil supplied with water almost to the point of saturation, and almost entirely unfrozen. A period of persistent rains and snows set in immediately, and for nearly four weeks there was practically no relief. That a flood of great proportions was imminent very soon became apparent, the only questions in doubt being the crest stage, and the probability of the occurrence of cold waves of sufficient intensity to check the rising waters. This question of the probability of cold waves was a very disturbing element in the situation as the season was very early, and severe January floods almost entirely unknown. An added element of danger was the fact that at the beginning of the month the river was much above the normal January stage, and rising, as a result of the rains and high temperature of the last two days of December, 1906.

The flood from Pittsburg, Pa., to Wheeling, W. Va., was of moderate character, the crest stage varying from 1.2 feet at the former to 0.9 foot above the flood stage at the latter place. Warnings were issued twenty-four hours in advance and no damage of consequence resulted. The one especial feature of the flood at Pittsburg was its long duration. Ordinarily a tide will run out in one or two days, but in this instance the water was near the flood stage from the 13th to the 21st, inclusive, a period of nine days, a result, of course, of the persistent rains.

In the Parkersburg district the flood conditions were a little more pronounced, with a crest stage at Parkersburg on the 21st, of 40.1 feet, 5.1 feet above the flood stage. There were three distinct flood crests in this district; on the 17th, 18th, and 21st. The first two were due to flood tides from the Muskingum and Little Kanawha rivers, while the last was the main flood wave. The river was above the flood stage at Parkersburg from the 17th to the 22d, inclusive; but aside from the inconvenience and discomfort, and the interruption of business, the actual loss in the district probably did not exceed \$25,000.

From the mouth of the Great Kanawha River to Cairo conditions were greatly intensified, and the crest stages ranged from 8 to 15 feet above the flood stages, except between Paducah and Cairo. In the Cincinnati district warnings were first sent out on the 14th, and daily thereafter until the decline was well under way. While no undue alarming reports were issued, no effort was spared to impress upon all interested the extreme gravity of the situation, and the immediate necessity of using every precaution for the preservation of life and property. The crest stage at Cincinnati was 65.2 feet on the 21st, 15.2 feet above the flood stage. The river was above the 50-foot stage for eleven days, and above the 60-foot stage for five days. Had it not been for the timely occurrence of a cold wave between the 21st and 23d, it is very probable that the flood would have reached a height of 67 feet and ranked below that of 1884 only, as the high-water stage of February 15, 1883, was 66.4 feet. Stages above 60 feet at Cincinnati are of rare occurrence, as will be seen from the subjoined statement.

Year.	Date.	Stage.
1832 .....	February 18 .....	64.3
1847 .....	December 17 .....	63.7
1883 .....	February 15 .....	66.4
1884 .....	February 14 .....	71.1
1897 .....	February 26 .....	61.2
1898 .....	March 29 .....	61.4
1907 .....	January 21 .....	65.2

Never before was flood information in such general demand, and in respect to this, the Price Current took occasion to remark that "The Weather Bureau Office at Cincinnati has rendered very important service incident to the flood conditions in furnishing current information, and in pointing out what might be expected. The gradual rise, with the warnings, made it possible to do a great deal preparatory to conditions of inundation". Nevertheless there was much suffering and loss, the former beyond adequate description, and the latter beyond estimate. However, the business interests of Cincinnati were interrupted to a less extent than might have been expected under the circumstances, since the submerged portion of the city constitutes but a small percentage of its area.

At Portsmouth, Ohio, the water rose over the north end levee, completely flooding that section of the city, and the casualties incident to such situations were reported. The actual property loss amounted to about \$125,000; but the outlay necessitated by the flood, and the value of the time lost by the business interests can not be estimated. The city of Maysville, Ky., suffered, perhaps, a greater proportionate loss than any other community. About one quarter of the city was submerged, business paralyzed, and railroad traffic suspended for several days. Heating appliances were flooded, the supply of gas cut off, and street car traffic discontinued. The highest stage of the water was 60.3 feet at 1 a. m. of the 21st. This was 5.4 feet less than the high-water stage of February 14, 1884, and 0.2 foot less than that of February 18 and 19, 1832.

Similar conditions, at times more or less aggravated, prevailed in the Louisville, Evansville, and Cairo districts. At Louisville the high-water stage of 41.4 feet on the 22d was 5.3 feet below the 1884 stage and the river was above the flood stage of 28 feet from the 17th to the 27th, inclusive. The property loss and damage amounted to between \$400,000 and \$500,000 and about 2000 acres, or one-seventh of the city's area, was under water. There was also much damage along the tributary streams in the State of Kentucky, and many towns and villages were cut off from the outside world.

Below Louisville the situation was rendered more serious by the fact that a flood of considerable proportions was still in progress when the great rise arrived from the upper river. It should have been stated before that this early flood in the lower river contributed much toward the prolongation of the flood crests in the upper Ohio.

At Evansville the river past the flood stage of 35 feet on the

4th and remained above until February 2, a period of thirty days. The maximum stage was 46.2 feet, on January 27 and 28. The actual damage in the district, including the Green River country, was surprisingly small, probably less than \$200,000. The greatest loss was probably that of the corn in the bottom lands. There was, of course, the usual interruption of certain classes of business, and the expenses incident to the protection of property.

The crest stage of 50.3 feet was reached at Cairo on the 27th, and the river was above the flood stage of 45 feet from January 21 to February 5, a period of sixteen days. As over the upper river districts, the losses were not at all great, considering the duration and extent of the flood. Some corn, stock, fencing, and outbuildings were carried away, but not in great quantity. As a matter of fact, there was probably more damage done along the lower Wabash River, altho, as along the Ohio River, the warnings of the Weather Bureau had enabled the inhabitants to remove large quantities of property.

The town of Birdspoint, Mo., on the Mississippi River, immediately opposite the mouth of the Ohio, was almost completely inundated. The Cotton Belt Railway Company attempted to close a gap in the levee with sandbags, but the work was abandoned, and both the Cotton Belt and Iron Mountain railways were shut out from the town for eleven days; thousands of acres of land were overflowed and between 60,000 and 70,000 bushels of corn destroyed.

It is the opinion of Mr. P. H. Smyth, official in charge of the local office of the Weather Bureau at Cairo, that the sandbag work at Birdspoint increased the flood plane at Cairo a half foot, and possibly more. He is also of the opinion that the proposed new work at the same place will have a decided effect upon the future stages of the Ohio and Mississippi rivers in the vicinity of Cairo. The object of the work is to close a gap in the embankment thru which the flood waters now spread out over almost 100,000 acres of lowlands, and when the gap is closed the gage relations between Cairo and adjacent places are likely to be materially disturbed at high stages.

Station.	Forecast stage.	Actual stage.	Difference.
Pittsburg, Pa. ....	23.5	23.2	-0.3
Wheeling, W. Va. ....	36.0	36.9	+0.9
Parkersburg, W. Va. ....	39.0 to 40.0	40.1	+0.1
Cincinnati, Ohio. ....	65.0 or a little over.	65.2	0.0
Madison, Ind. ....	56.5 to 57.0	56.7	0.0
Louisville, Ky. ....	40.5 to 41.0	41.4	+0.4
Evansville, Ind. ....	46.0	46.2	+0.2
Mount Vernon, Ind. ....	48.5	48.5	0.0
Paducah, Ky. ....	45.0 to 46.0	45.7	0.0
Cairo, Ill. ....	50.0 to 50.6	50.4	0.0
Mount Carmel, Ill. ....	24.0 to 25.0	24.5	0.0

The following table shows the dates between which the river remained above the flood stage, at various stations, together with the number of days. A special hydrograph of the Ohio River, showing the stages from day to day, will be found on Chart IX.

*Above flood stage.*

Station.	From—	To—	No. of days.
Pittsburg, Pa. ....	January 20	January 20	1
Wheeling, W. Va. ....	January 20	January 21	2
Parkersburg, W. Va. ....	January 17	January 22	6
Point Pleasant, W. Va. ....	January 16	January 24	9
Huntington, W. Va. ....	January 17	January 23	7
Catlettsburg, Ky. ....	January 17	January 24	8
Portsmouth, Ohio. ....	January 17	January 25	9
Maysville, Ky. ....	January 17	January 25	9
Cincinnati, Ohio. ....	January 16	January 26	11
Madison, Ind. ....	January 17	January 26	10
Louisville, Ky. ....	January 17	January 27	11
Evansville, Ind. ....	January 4	February 2	30
Mount Vernon, Ind. ....	January 5	February 4	31
Paducah, Ky. ....	January 21	February 5	16
Cairo, Ill. ....	January 21	February 5	16

The warnings of the Weather Bureau during the entire flood were issued as far in advance as the varying conditions and

circumstances would permit. That they were accurate in practically every particular is evidenced by the very small losses as compared with those resulting from the great floods of previous years. In the preceding tables will be found the forecast and the actual crest stages, and the differences between them at the various stations.

General floods also occurred over the interior rivers of Ohio from the 4th to the 6th, and from the 19th to the 23d, all inclusive, for which warnings were issued at the proper time. The warnings proved to be very effective, and no serious damage was reported.

The lower Tennessee flood of the first week of the month did no material damage. Warnings were issued on the 2d, 3d, and 4th, and a stage of 24 feet forecast for Johnsonville, Tenn. On the morning of the 6th the stage of the river at that place was 24.1 feet. The warnings were of great benefit to the lumber and farming interests.

There was a severe flood and ice gorge in the Grand River of Michigan caused by the warm and heavy rains of the 19th and 20th, and the cold wave of the 21st. To the rains was added the water from about two and one-half inches of snow that was melted and carried into the river. A large ice gorge formed at the village of Portland, Mich., raising the water above the flood stage of 12 feet during the night of January 21 and 22. While the jam checked the rise in the lower river, it created a serious situation that was soon recognized, and on the morning of the 23d general warnings for high water were issued from the local office of the Weather Bureau at Grand Rapids. At 11 a. m. of the 24th the river at Grand Rapids stood at 18.5 feet, 7.5 feet above the flood stage and 1.9 feet below the high-water stage of March 26-27, 1904.

After this time the river began to fall slowly, but at the end of the month it was still one foot above the flood stage, with several ice gorges still intact. Special bulletins and advices were issued frequently until the water subsided, and the work of the Weather Bureau was commended in the highest terms, both officially and otherwise. The conditions were about as severe as any that have been experienced in recent years, and the work of forecasting was attended by numerous difficulties. At Portland all of the factories were compelled to close, and large portions of the business and residential districts were rendered untenable. At Grand Rapids nearly one hundred factories were closed down, throwing out of employment over six thousand men. Basements were flooded with from two to five feet of water, fires were extinguished, elevators stopt, and business generally inconvenienced. The warnings, however, altho given on comparatively short notice, were effective in saving nearly all property capable of removal or protection.

There was some danger of a flood in the Hudson River in the vicinity of Troy and Albany on account of an ice gorge near Stuyvesant, N. Y., and preliminary warnings to this effect were issued on the 3d. The breaking of the ice relieved the situation after the river had past the flood stage at Troy, and nearly reached it at Albany. High water also did some damage in portions of the Mohawk Valley.

There were two floods in the Illinois River. The first was a moderate one for which warnings were issued from the 8th to the 11th, inclusive. While the crest stages were above the flood limits, no damage of consequence was done. The second flood was caused by the heavy rains about the middle of the month, and warnings were issued on the 19th, 20th, and 21st for stages several feet above the flood limit. Stages as follows were recorded: La Salle, Ill., 28.6 feet, 10.6 feet above flood stage; Peoria, Ill., 20.4 feet, 6.4 feet above flood stage, and Beardstown, Ill., 18.3 feet, 6.3 feet above the flood stage.

At La Salle the flood was the most disastrous for many years, and the worst ever known at this season of the year. Many buildings were flooded, and much damage done. The pontoon bridge at Lacon, Ill., 25 miles above Peoria, was car-

ried away, and along the lower river there was considerable damage to bridges, farm lands, and railroad property.

Heavy rains on the 18th caused a marked rise in the Neosho River. The rise came very rapidly, but it was nevertheless possible to issue warnings for flood stages at Oswego, Kan., by January 20, and for continued high water at Iola, Kans. Stages of 13.4 feet and 21.0 feet were reached at Iola and Oswego, 3.4 and 1.0 feet, respectively, above flood stages. No damage of great consequence was reported, altho the smaller streams overflowed their banks in many places.

Flood stages also occurred in the White River of Arkansas. There were two floods in the upper river, and one in the lower. Warnings were issued on the 3d and 10th, and no damage was done along the upper river. At Clarendon, Ark., the river remained above the flood stage of 30 feet from the 5th to the 26th, inclusive, with a crest stage of 32.5 feet from the 9th to the 11th, inclusive, but the only loss reported was that of about two hundred head of cattle and some hogs in the bottoms near Clarendon.

The Willamette River flood from the 4th to the 6th, inclusive, was checked by cold weather, resulting in stages somewhat lower than had been at first anticipated, and, at the same time, reducing the damage to a minimum. The flood

was caused by the heavy rains from the 2d to the 4th, inclusive, falling upon an already saturated watershed, and the outlook was very serious until the arrival of the cold weather. As it was, flood stages were exceeded, except along the extreme lower reaches, but not to the extent that had at first been indicated.

At the end of the month the Missouri River was practically frozen as far south as Omaha, and the ice was 11 inches in thickness at Sioux City, Iowa. The Mississippi River was frozen to Leclaire, Iowa. Floating ice reached to only a short distance below Cairo.

The New England rivers remained generally frozen, while the Lehigh and upper Delaware were closed for a portion of the month.

The highest and lowest water, mean stage, and monthly range at 291 river stations are given in Table VI. Hydrographs for typical points on seven principal rivers are shown on Chart I. The stations selected for charting are Keokuk, St. Louis, Memphis, Vicksburg, and New Orleans, on the Mississippi; Cincinnati and Cairo, on the Ohio; Nashville, on the Cumberland; Johnsonville, on the Tennessee; Kansas City, on the Missouri; Little Rock, on the Arkansas; and Shreveport, on the Red.—*H. C. Frankenfield, Professor of Meteorology.*

## SPECIAL ARTICLES, NOTES, AND EXTRACTS.

### THE KINGSTON EARTHQUAKE.

By Prof. C. F. MARVIN. Dated January 22, 1907.

The following bulletin, prepared at the Weather Bureau, was given to the press associations on the afternoon of Tuesday, January 15, 1907, at a time when, according to the earliest dispatches, a great earthquake was supposed to have occurred at Kingston on that day; whereas it will be noted that the record referred to in this bulletin relates to Monday, January 14. It finally turned out that the earthquake had actually occurred twenty-four hours before news of it reached the United States, owing to the complete interruption of telegraph and cable communications.

The seismographs at the Weather Bureau recorded a distant earthquake, of moderate intensity, on the afternoon of January 14, 1907, beginning at 3 hours 38 minutes 23 seconds p. m., seventy-fifth meridian time, or 8 hours 38 minutes 23 seconds, Greenwich meridian. The relatively stronger portion of the motion was greatest in the east-west component and lasted from 3:45 p. m. until 3:52 p. m.

The maximum amplitude of motion in the east-west direction was only about one-fiftieth of an inch.

The earthquake recorded as above is undoubtedly the same as one that is reported to have occurred in the island of Jamaica at the same date and hour. The press reports are as yet very indefinite as to the time when the earthquake occurred at Kingston. By the use of well-known seismological formulas we may deduce, from the records made at Washington, that at its origin this earthquake began at 3 hours 33 minutes 9 seconds, p. m., seventy-fifth meridian time, January 14.

Judging from the magnitude of the motion as recorded at Washington we regard the present disturbance as of slight intensity when compared with other recent great earthquakes, such as those at San Francisco and Valparaiso, and that in the Indian Ocean on October 1, 1906. This is especially true in view of the fact that the distance of Kingston from Washington is only about 1420 miles, while San Francisco is distant 2435 miles, and Valparaiso 4900 miles, or nearly three and a half times as far as Kingston, and both Kingston and Valparaiso are almost exactly south of Washington. The amplitude of the motion at Washington, in the present case, is distinctly less than in either of these other great earthquakes, and we may therefore conclude that the violence of the "Kingston earthquake" was also less at its origin.

Attention is called to an interesting feature in these earthquake records, which confirm, in a noticeable degree, certain theories that have been advanced in regard to the different kinds of wave motion that occur during an earthquake. Kingston and Washington are very nearly on the same geographical meridian, Kingston being only 15 minutes of arc east of Washington, at a distance of something over 1400 miles. In other words the direct line of propagation was, in this case, exactly from south to north. The two seismograph pendu-

lums at Washington are so placed as to record north-south and east-west components, respectively.

The details of the several phases characteristic of records of distant earthquakes are given in the following table:

*Kingston earthquake, afternoon of January 14, 1907, seventy-fifth meridian time.*

#### TIME OF EARTHQUAKE.

	N.-S. component.			E.-W. component.		
	<i>h.</i>	<i>m.</i>	<i>s.</i>	<i>h.</i>	<i>m.</i>	<i>s.</i>
First preliminary tremors began January 14, 1907, at.....	3	38	23	Absent.		
Second preliminary tremors began at.....	3	42	50	3	42	50
Principal portion began at.....	3	46	45	3	46	38
Principal portion ended at.....	3	55	03	3	55	03
End of earthquake at.....	4	40	23	4	49	23

#### DURATION OF PHASES.

	<i>h.</i>	<i>m.</i>	<i>s.</i>	<i>h.</i>	<i>m.</i>	<i>s.</i>
Duration of first preliminary tremors.....	0	04	27	Absent.		
Duration of second preliminary tremors.....	0	03	55	0	03	48
Duration of principal portion.....	0	08	18	0	08	25
Total duration of earthquake.....	1	02	00	1	06	33
Period of pendulum.....	20 secs.			20 secs.		
Magnification of record.....	25 times.			20 times.		
Maximum double amplitude of actual displacement of the earth at the seismograph.....	<i>mm.</i>			<i>mm.</i>		
Amount.....	0.11			0.55		
Time.....	3 <sup>h</sup> 54 <sup>m</sup>			3 <sup>h</sup> 50 <sup>m</sup> 3 <sup>h</sup> 51 <sup>m</sup>		

**NOTES.**—*North-south component:* The period of the waves in the first portion of the "principal portion" was about 10 seconds, with very small amplitude, followed by complex waves of small amplitude beginning at 3:50:23 p. m., of 17-second periods; again followed by waves of shorter period and small amplitude.

*East-west component:* The first preliminary tremors appear to be absent. The second preliminary tremors are very faint, but appear to begin simultaneously with the second preliminary tremors in the north-south component. The periods in the principal portion are about 10 seconds at first; then complex and long, 20 to 30 seconds; then, from 3:48 to 3:50 p. m., large and regular, at about 20-second periods, ending with maximum waves of 10- to 12-second periods.